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MODERN CARBONATE SEDIMENTS IN SHELL KEY BASIN, FLORIDA BAY

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ABSTRACT

Shell Key Basin is one of the many local basins (= 'lakes') defined by the anastomosing carbonate mudbanks and mangrove-covered islands in the large, triangular-shaped Florida Bay. The basin, approximately 2.5 miles across, is bordered on the southeast by Upper Matecumbe Key and on the other three sides by mudbanks and mangrove-covered islands. The center of the basin has a thin sediment cover on the Miami Formation (Pleistocene) so that it is saucer shaped in cross section. Sonic depth profiles and probing through the soft sediment to the bedrock floor indicates that the same microkarst features are under the basin as are exposed farther north on the mainland. Sediments accumulating in the basin has a bimodal size distribution which is the result of fine aragonitic needles secreted by algae, especially *Penicillus*, and abraded bioclastic debris. Distribution of the sediment is dependent mainly on periodic storm-driven currents. Cores through the slightly asymmetrical mudbanks reveal a soft fine-grained sediment with coarse layers (=Storm layers) penetrated by roots from the *Thalassia* grass on the surface. In general, the salinity and CO2 of the water decrease as pH and turbidity increase; salinity changes are the result of dilution and circulation; CO2 changes result from vegetation, light, and temperature; pH is affected by CO2 production and circulation; and turbidity is due to depth, agitation, and availability of loose material. Geographic position of age dates of the basal peat in the bay indicate an anomalous situation where there seems to be a topographic low area roughly parallel to the present keys and extending north seemingly an extension with present-day drainage.

INTRODUCTION

Florida Bay is one of the most studied areas of modern carbonate sediment in the world. This is due undoubtedly to ease in accessibility, and diversity of interesting features and processes exhibited in the bay. In a region of shallow-water carbonate sedimentation many processes whether physical, chemical, or biological are related, but the relationships need to be elucidated. Many problems including mudbank and island origin, mudbank relief maintenance, and carbonate genesis still remain unanswered in spite of many comprehensive studies (Ginsburg, 1956, 1957; Gorsline, 1963; Taft and Harbaugh, 1964; Stockman, Ginsburg, and Shinn, 1967; and Enos and Perkins, 1977).

Although Stockman et al. (1967) established the dominance of biological precipitation of carbonate in the Florida Bay, the role of inorganic precipitation yet remains unclear. Shinn (1983, pers. comm.) for example, is restudying the cause of whitings in the bay on an assumption that they may be inorganic. Therefore, even in an intensely studied area, new data may provide information to change established interpretations.

The main objective of this paper focuses on the problem of carbonate genesis as related to a small basin in the bay. By studying different processes and their interrelations in Shell Key Basin, information can be obtained that may be extrapolated to the bay in general.

REGIONAL SETTING

The triangular-shaped, 1500-sq km area is bounded on the north by the mangrove-lined mainland and on the southeast by the bead-like string of Florida Keys; to the southwest, it is open to the Gulf of Mexico (Fig. 1). The shallow bay is divided into a series of anastamosing near-linear mudbanks (piles of soft carbonate sediment) outlining what the natives term lakes (= basins). The mudbank system inpedes circulation with the surrounding bodies of water, causing the bay's interior to be essentially tideless. Water depth in the bay ranges upto about 10 feet in the deepest parts and the bay is floored by bedrock of the Miami Limestone (Pleistocene).

Freshwater empties into the bay from the Everglades on the north and marine water intermingle through openings between the Keys on the southeast. At present, calcium carbonate is being generated biogenically in the bay and distributed mainly by storm-driven currents. Tidal currents play a larger role in sediment distribution in the Atlantic subenvironment, which is defined by Ginsburg (1956) includes Shell Key Basin. Much of the carbonate is being generated in situ by algae and the remaining material is composed mainly of mollusc shell fragments. Sediments reflect this dual origin by a bimodal-size distribution. The banks generally are thicker, wider, and less numerous in the western part of the bay than in the eastern part. Islands are present at the intersection of many of the mudbanks. Most islands are oval shaped, mangrove covered, and just a foot or two above the water level.

The bay developed in a tectonically stable area. The Miocene, Pliocene, and Pleistocene sediments record transgressions and regressions of the sea. For the past 5,000 years sealevel has been rising slowly again, in response to melting of glaciers caused by a general warming of global climate.

SHELL KEY BASIN

Shell Key Basin is located just northwest of Islamorada on Upper Matacumbe Key. Cotton Key is on the north and Shell Key on the southwest and mudbanks extend between the keys so that the basin is almost enclosed. The mudbank extending west from Cotton Key does not connect with the one extending north from Shell Key, allowing limited circulation with Cotton Key Basin to the north. Other openings in the banks include the inland boat channel on the southwest and west side all of which have a profound effect on the circulation in the basin. A large tidal delta is forming on the southern side between Islamorada and Shell Key.

The basin is about 2.5 miles across and 8-ft deep in the center part giving it a shovel shape (Fig. 2A). The mangrove-covered Cotton and Shell Keys are oval in plane view and in cross section are saucer shaped with the rims slightly higher than the interior. The bank are covered by the sea grass, *Thalassia testudinum*, and portions of the basin have a firm substrate as indicated by the loggerhead and other sponges. There is a large aggregation of algae, mainly *Penicillus, Halimeda*, and *Udotea*, and other marine organisms living in the basin.

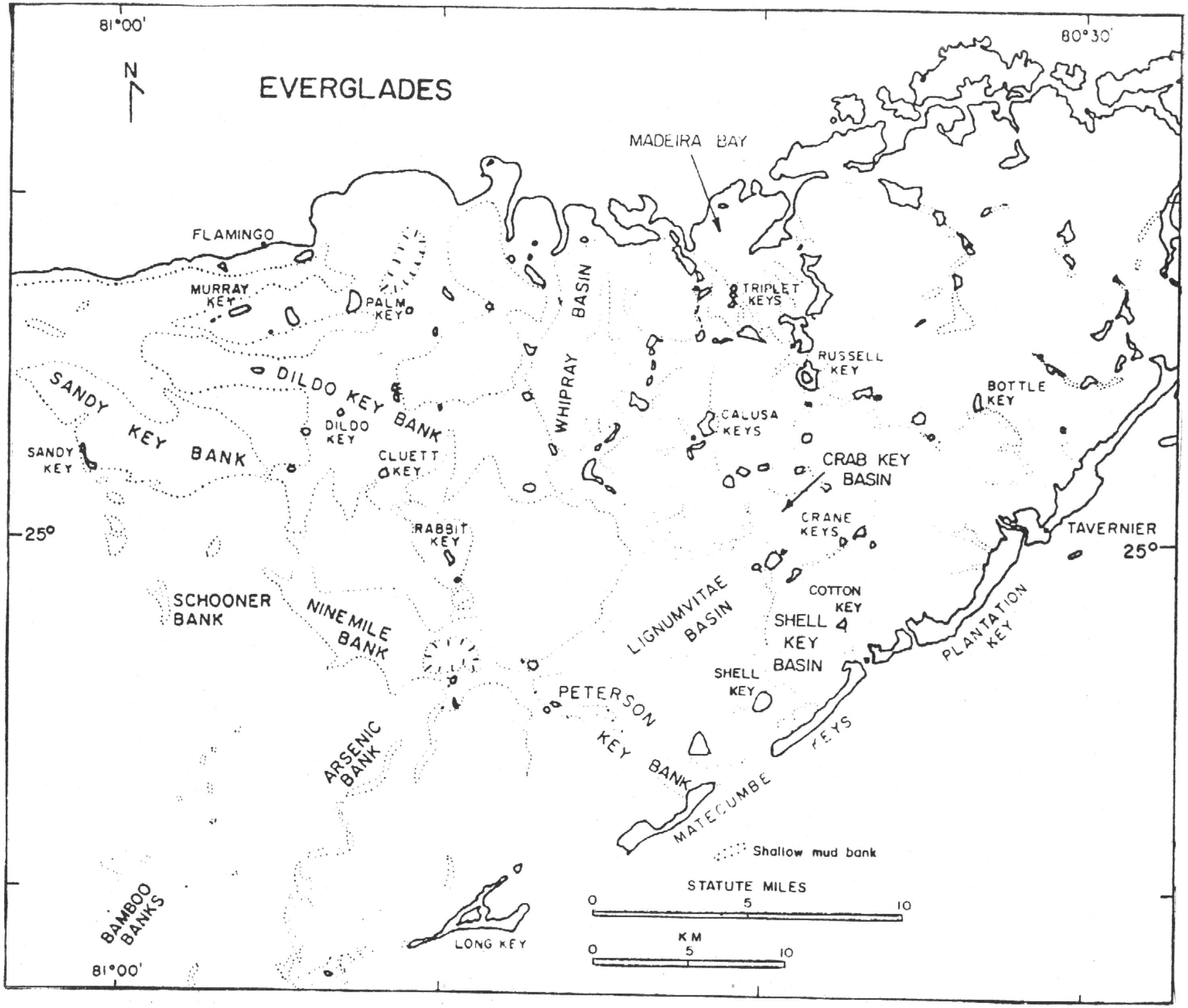


Figure 1. Part of Florida Bay showing location of Shell Key Basin (from Enos and Perkins, 1979).

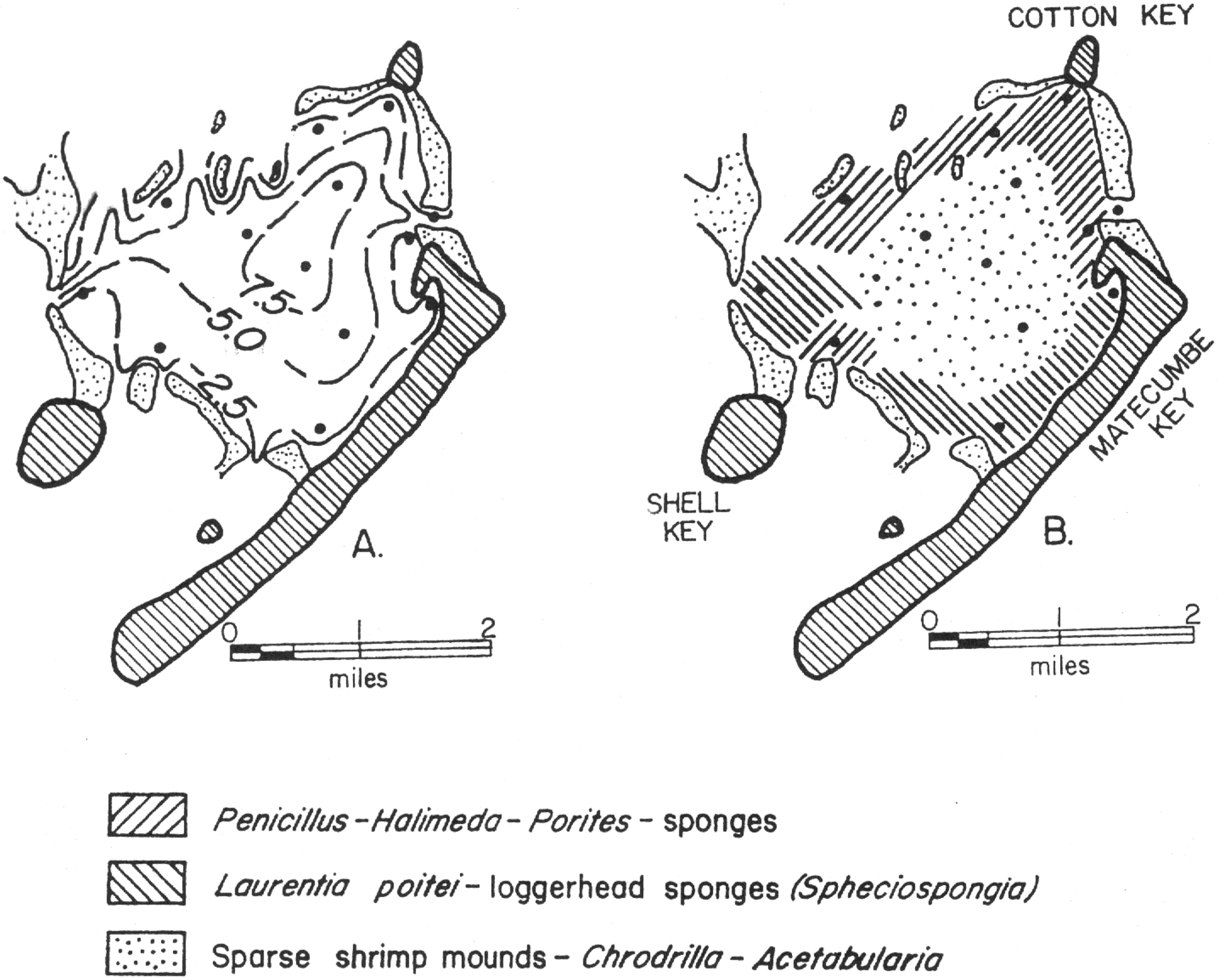


Figure 2. A, Water depth in Shell Key Basin, CI 2.5 ft. Note shovel shape slightly elongate to northeast and flat on southwest side. Maximum depth is about 8 ft. Dots show location of sampling stations. B, Distribution of floral and faunal bottom communities in basin.

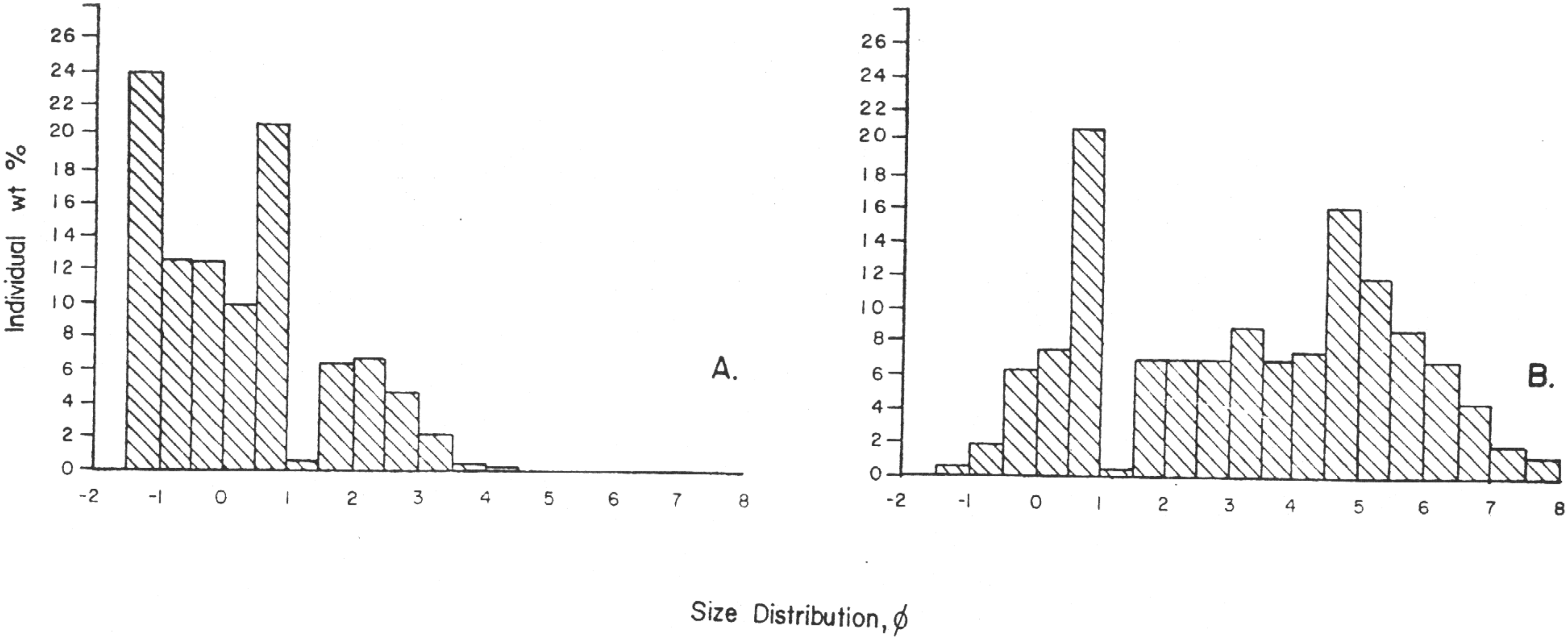


Figure 3. Size distribution for (A) tidal-channel suite (station 10), and (b) center of basin (station 12). Tidal-channel suite is characterized by bimodal distribution with peaks centered about -1.25 and 0.75 0.

Most of the fauna and flora are concentrated in the shallows around the edge of the basin (Fig. 2B). *Penicillus, Halimeda, Udotea,* and other algae as well as the coral, *Porites*, are abundant in the shallow warm weaters in the northern parts, whereas they are absent or nearly so in the deeper parts of the basin. The red algae (*Rhodophycaea*) *Laurencia poitei* and loggerhead sponges (*Spheciospongia vesparia*) occur along the southern perimeter of the basin. Only conical-shaped mounds presumably made by shrimp occur in the deeper parts of the center of the basin along with a few sponges and sparse *Thalassia*. Locally the encrusting bryozoan *Schizoporella floridana* is an important element of the fauna.

The mudbanks which for the western side of the basin are just yards wide and become emergent at low tide. The banks are composed of light-gray micritic carbonate mud. The north and west sides of the banks are slighly steeper and firmer because storms from the northeast wash and winnow the fines to the south concentrating the coarser material on those sides. Grass is more prevalent on the south and east sides (leeward) of the banks where the roots serve to bind and stabilize the banks and the blades act as baffles and trap the mud. Gorsline (1963) claims that gentle clockwise gyre currents sweep fines up onto the banks leaving a lag on the bottom.

The sediment accumulating in the basin has a bimodal distribution reflecting the sources of fine aragonitic needle secreted by algae, especially *Penicillus*, and abraded bioclastic material, mostly fragmented mollusc shells, Halimeda fragments, and the foraminifera *Peneroplis proteus* and *Archaias angulatus* (Fig. 3).

METHOD OF ANALYSIS

The scope of this study dictated that sampling stations be established in the basin and sampling scheme was used similar to that of Lynts (1966). Thirteen stations in the basin were selected randomly (a fourteenth was added later). A series of in situ chemical tests were conducted at each station and grab samples taken. Stations were reoccupied by resection using fixed landmarks and marine marker buoys. The stations were occupied and sampled in January 1980, 1981, 1982, and 1983, July 1982, and April 1983.

At each station several parameters of the sediment-water interface were measured including (1) depth, (2) temperature, (3) salinity, (4) pH, (5) dissolved CO_2 and (6) dissolved O_2. The parameters were measured in the field to minimize chemical change with time or transportation.

Sediment samples were processed by wet sieving through a series of standard phi meshes. It was necessary to wet sieve samples because the clay fraction in the carbonate sediments will not completely deflocculate after drying (Lynts, 1966). The silt-clay fractions were determined using standard pipette methods (Krumbein and Pettijohn, 1938).

Our interest in the upper few centimeters of sediment is based on the fact that the interface is both biologically active and chemically reactive (Volkman and Oppenheimer, 1959). The physical properties of sediments, as controlled by biological processes, may have a major affect on sedimentation, sediment transport, and the historical fossil record. Biological, chemical, and sedimentological processes are interrelated through the mechanism of bioturbation involving the transport of particles, as well as pumping water into, and out of, the bottom.

Depth measurements were made by sounding at each station with a length of core tubing. Temperature was measured by suspending a thermometer just above the bottom for a period long enough to let the reading stabilize. Water samples for chemical analysis were collected in a sealed container just above the bottom and the chemical parameters then measured on site using a Hach DR-EL/1 portable water-analysis kit.

SEDIMENT ANALYSES

Grain-size analyses revealed a distribution that can be divided into two distinct suites. The majority of sediment samples have the classic Florida Bay bimodal distribution with the peaks at 0.5 and 3.0. The size-distribution suite does not change significantly in the basin except in tidal channels where the sediments are coarser because the finer fraction (<3.5 phi) has been winnowed out by currents (Fig. 3).

The 0.5 phi size is dominated by molluscan fragments suggesting that this size is the limit to which bioclastic material can be abraded by normal processes in the basin. Sample proximity to areas of better circulation (primarily tidal channels) determined the dominance of the coarse fraction between 0.25 and 0.75 phi composed primarily of molluscan debris. Conversely, sediments collected in poor-circulation and low-energy areas of the basin have larger fractions of silt- and clay-size particler (4-9 phi).

Distribution of sediments in the basin seemingly is affected to a considerable extent by storms, especially hurricanes that occur frequently in the area. The muds are extremely cohesive requiring relatively high amounts of energy to be put into suspension, but once suspended they are slow to settle. The water may remain cloudy with suspended sediment for days after squalls or minor storms..

There is a recognized sequence of environmental facies in the bay area: freshwater marl (pond), peat (swamp), shallow bay ("lake"), mudbank (bay), and island (supratidal) (Enos and Perkins, 1979). This sequence records the slowly rising sea level through the past 5,000 years. Nonetheless, not all depositional environments are represented at any one location.

The recent sedimentation has taken place on a bedrock (or 'basement') of the bryozoan facies of the Miami Limestone of Pleistocene age (Enos and Perkins, 1979). The flat-lying unit dips gently to the southwest only a few feet per mile. There are known bedrock highs under Arsnicker Keys and East Key, and a bedrock low that is near and parallels the main keys (E.A. Shinn, 1983, pers. comm.). Only two bedrock cores are known to have been taken, one was on Cluett Key (Enos and Perkins, 1979) and the other on western Ninemile Bank (P. Enos, 1983, pers. comm.).

WATER ANALYSES

Water samples were taken at 13 stations in the basin through a period of two years. They were analyzed with a portable water-chemistry kit at each site on location. Determinations were made for salinity, pH, CO_2, temperature, and turbidity. It was also possible to make O_2 determinations within the last year of the study.

Salinity: Salinity ranges from 29 to 42 ppt (normal marine = 35). In any particular day the values vary up to 4 ppt in the basin forming several small pods of higher than average salinity depending on local circumstances (Fig. 4A). Changes in salinity are the result of dilution and circulation. Dilution is due to rain, runoff (from the keys), and movement of freshwater out of the bedrock. Circulation is the result of connections with the open ocean and water movement through channels in and out of adjacent 'lakes.'

Carbon Dioxide (CO_2): The range of carbon dioxide is from 13 to 36 mg/1,with the highest values in areas where there is a concentration of molluscs. In general the high CO_2 concentrations are around the edges of the basin where the molluscs thrive in the shallow warm waters (Fig. 4B). Seemingly the ratio of CO_2 - depleting algae to CO_2 generating molluscs is

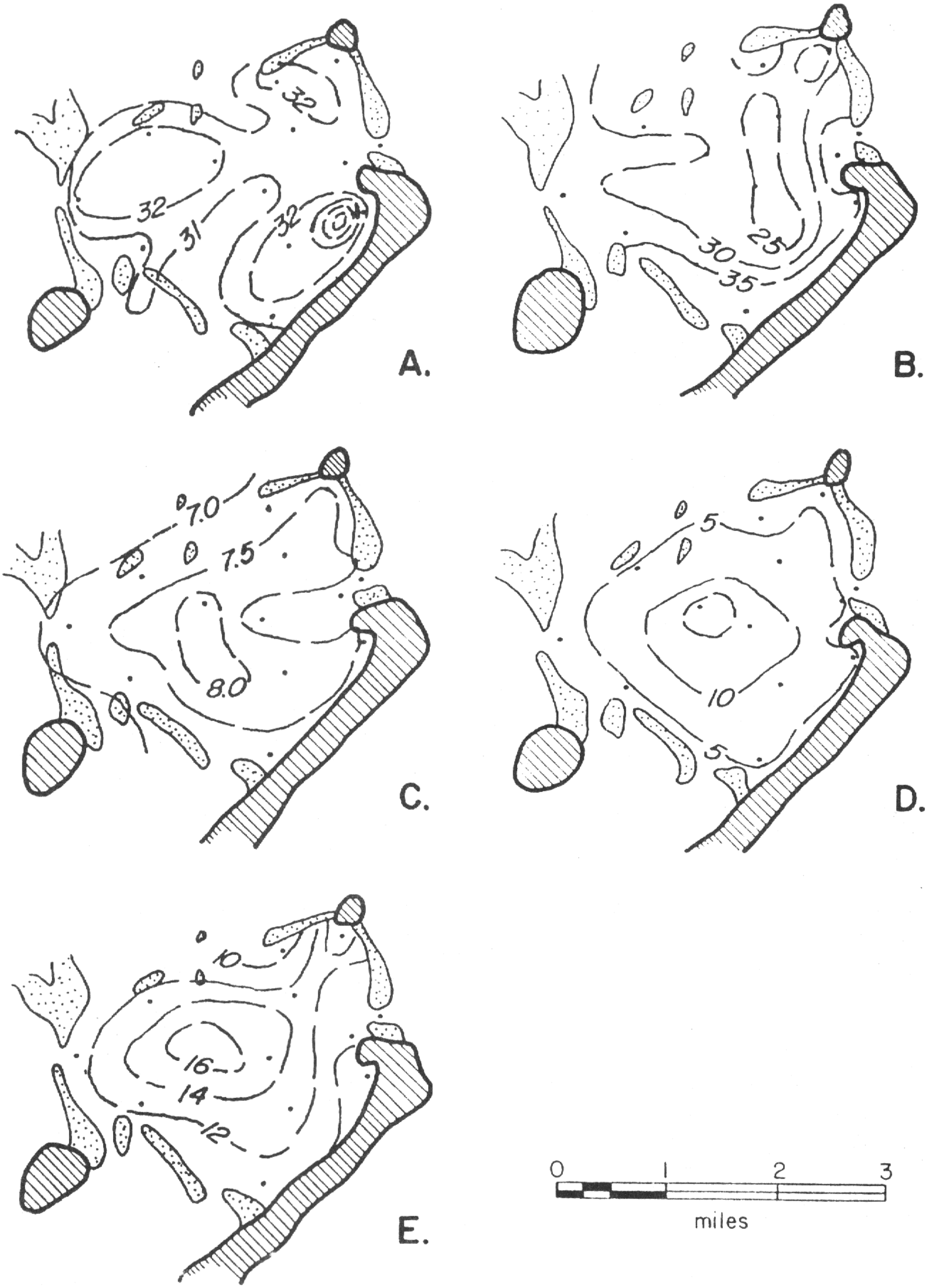


Figure 4. All samples taken just above bottom. A,B,C, and D taken in July 1982; E taken in April 1983. A, salinity, CI = 1 ppt; B, CO2 mg/1, CI = 5 mg/1, CI = 5 mg/1; C, pH, CI = 0.5 units; D, turbidity, CI = 5 ftu; and E, O2, CI = 2 mg/1.

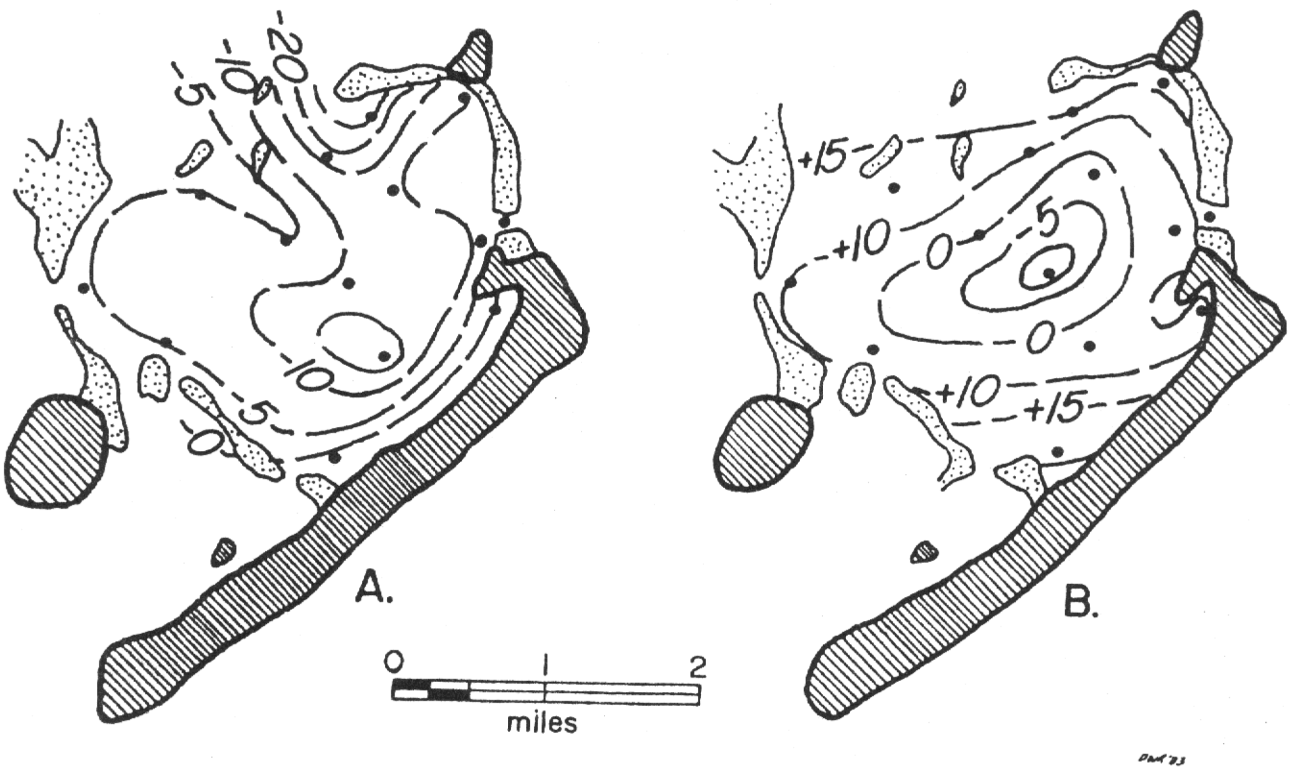


Figure 5. A, Change in CO2 values from day to night. Note greatest change is in middle and northern part of basin where readings are less at night. B, Change in O2 values from day to night. Greatest change occurs around perimeter of basin where values are higher at night.

Table 1. Statistical data on seasonal changes in Shell Key Basin water chemistry

variable / date	Salinity, ppt		pH		temperature, °C		CO_2, mg/l		turbidity, ftu		O_2, mg/l	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
January 1982	32.2	2.1	7.7	0.2	16.3	1.2	28.0	4.0	11.5	3.3	5.9	0.6
July 1982	31.9	1.6	7.5	0.3	28.3	0.6	30.6	4.7	6.8	5.4	13.0	3.9

Table 2. Differences in water chemistry in Madeira Bay, Crab Key Basin and Shell Key Basin. All readings taken July 1982

variable / location	temperature, °C		salinity, ppt		CO_2, mg/l		pH		turbidity, ftu	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Madeira Bay	28.4	0.5	36.8	3.0	13.4	1.9	8.3	0.2	13.5	4.5
Crab Key Basin	28.7	0.8	32.1	1.8	22.7	7.4	7.4	0.3	9.4	3.3
Shell Key Basin	28.3	0.6	31.9	1.6	30.6	4.7	7.5	0.3	6.8	5.4

less in the shallow parts of the basin. Values are lower in the central part of the basin where there is a paucity of organisms. Although higher turbidity in the deeper parts of the basin could interfere with carbonate production by reducing photosynthesis of the calcareous algae, but in fact no part of the basin is deep enough to inhibit total carbonate production (maximum depth about 8 ft, thus within the photic zone).

pH: The pH ranges from 7.1 to 9.1 and is related to the concentration of carbonic acid (H_2CO_3). The precipitation of $CaCO_3$ is determined in large part by the pH of the environment. The overall process of carbonate precipitation may be summarized by the equation $CaCO_3$ + H_2CO_3= C^{++}+ $2HCO_3$. At low pH, where most dissolved carbonate exists as H_2CO_3, the forward reaction is favored whereas at high pH the reverse reaction leading to precipitation is favored, because OH^- reacts preferentially with the stronger acid, H_2CO_3 , rather than the weak HCO_3^- (Bathurst, 1975). The pH is about 7.7 (Table 1) in the basin and thus suggests it is too low to favor inorganic precipitation. Our results thus support the contention of Stockman, Ginsburg, and Shinn (1967) that most of the sediment is produced organically. Organisms that use calcium carbonate in the construction of their shells flourish in great abundance in waters near saturation with $CaCO_3$ because only a minor change in pH is needed to cause precipitation (Bathurst, 1975). In general, the pH is higher in the center parts of the basin (Fig. 4C). The lower alkalinity of the shallower parts of the basin suggests a greater production of CO_2 as reflected by higher concentrations of carbonic acid.

Turbidity: Values of turbidity range from 15 to 36 formazin turbidity units (ftu). In general it is more turbid in the deeper parts of the basin (Fig. 4D). Turbidity may be controlled primarily by agitation. During storms water in the entire basin is roiled and it may take several days for the suspended matter to settle. Turbidity is important because suspended clay- and silt-size particles strongly inhibit $CaCO_3$ production (Bathurst, 1975). Turbidity diminishes light transmission which interferes with photosynthesis, depressing the production of calcareous material produced by algae. Molluscs and other benthonic invertebrate carbonate producers also will have their feeding mechanisms clogged by suspended clay particles, thus reducing carbonate production.

Temperature: In summer the temperature varies little, only about 1^{o}C from an average of 28^{o}C. In the winter however, the temperature varies about 3^{o}C from an average of 16^{o}C with the colder portions in the deeper middle. Higher temperatures increase growth rates of blue-green algae suggesting that carbonate production in situ is greater on the banks. It is worth noting that inorganic precipitation of $CaCO_3$ is triggered by decreasing temperature as the solubility product of $CaCO_3$ lowers with temperature.

Dissolved Oxygen O_2: O_2 measures the abundance of plants which photosynthesize. High values occur where there are concentrations of these organisms unless masked by an abundance of organisms such as molluscs, which utilize the O_2 and give off CO_2. This is evident around the edges of the basin where there are low values of O_2 indicating the presence of organisms using the oxygen (Fig. 4E). The lower dissolved O_2 in the shallower areas also suggests prolific molluscan populations which produce biochemically precipitated carbonate.

Relation of the Variables: In general the salinity and CO_2 of the water decrease as the pH and turbidity increase. Thus salinity and CO_2 are high around the perimeter of the basin and pH and turbidity increase toward the center as does the O_2 . The relationship between these variables is a complex interaction of dilution, circulation, organisms, light, temperature, depth, agitation, and availability of loose material. In this complex ever-changing system there are short-range and long-range changes.

Changes: From our studies at least three changes in water chemistry have been recorded through time: diurnal, seasonal, and yearly. There are probably longer-range changes that we have not observed.

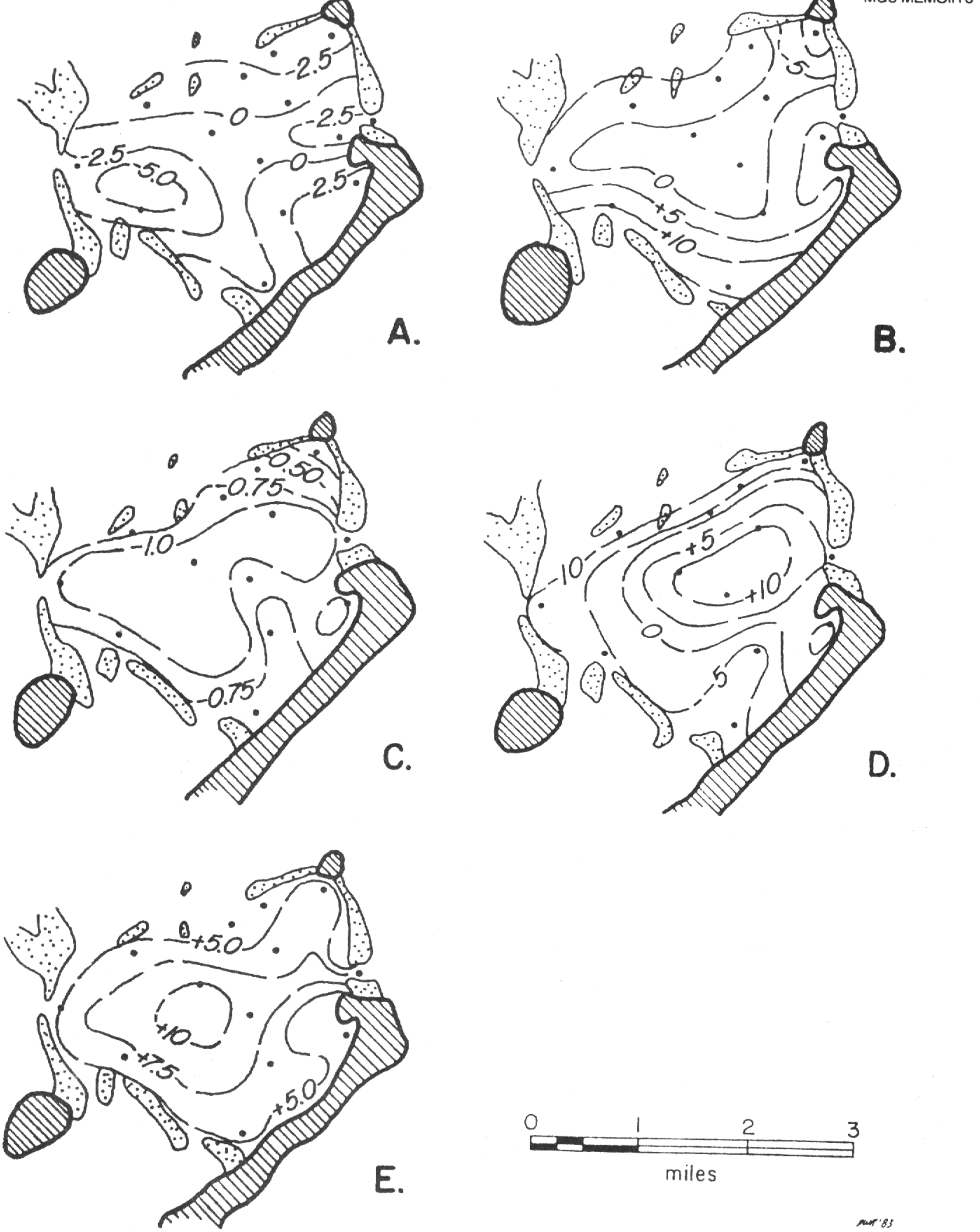


Figure 6. Changes in variables from dry (winter) to wet (summer) seasons. A,B,C, and E taken from January to July 1982; D taken from January to April 1983. A, salinity, CI = 2.5 units; B, CO2, CI = 5 units; C, pH, CI = 0.25 units; D, turbidity, CI = 5 units; E, O2, CI = 5 units.

The diurnal changes are striking especially in regard to CO_2 and O_2 which reflect biological activity. There is a decrease in the amount of CO_2 in the water at night due to the lack of production of the gas presumable by molluscs. The greatest change takes place toward the center of the basin and along the northern margin (Fig. 5A). In contrast the greatest change for O_2 is on the edge of the basin where there is an increase in O_2 in the water (Fig. 5B). The temperature is remarkably constant at night, whereas the pH reading are essentially the same as the daytime and salinity seems slightly higher.

Seasonal variations resulting from the dry winter months in contrast to the wet summer ones are about the same magnitude as the diurnal ones. Greater changes seems to be around the edges of the basin and reflect a circulation pattern between the opening out of the basin on the northeastern and western sides. The salinity pattern is elongated east-west reflecting the influence of the channel openings (Fig. 6A). The overall effect is a lessening of salinity in the center parts of the basin, probably as a result of increased rainfall; and an increase in salinity around the edges, probably as a result of increased evaporation in the shallows. The CO_2 increases over most of the basin due to increased organism activity in the warm months (Fig. 6B). The pH decreases slightly because of the increase in CO_2 ; an increase in the partial pressure of CO_2 also increases its availability to form carbonic acid. (Fig. 6C). O_2 increases noticeably in the warm seasons due to increased photosynthesis of the plants, especially the algae (Fig. 6E). The pattern is elongated east-west and reflects the influence of the channel openings. Statistical data for the variables in winter and summer are given in Table 1.

Patterns on the distribution of the variables from year to year are similar to those which are seasonal. The patterns are a reflection on the circulation in the basin whereas the actual values are the result, at least partially, of climatic factors. The most obvious difference is in the water temperature which averages about 16.3^{o}C in a cold winter to 21.2^{o}C in a warm one to a hot 28.3^{o}C in mid-summer. Both CO_2 and O_2 are relatively higher in the summer than in the winter. It is reasonable to assume that this change is the result of increased biological activity. The amount of dissolved CO_2 and thus the solubility of $CaCO_3$ decreases at higher temperatures according to studies of inorganic carbonate equilibria (Bathurst, 1975). Intense organic activity must be buffering the carbonate-bicarbonate system in Shell Key Basin to cause the higher readings during the Summer. The salinity and turbidity seem to depend more on local fluctuations.

Regional Variation: There is a definite regional variation in several variables. Studies were made in Crab Key Basin near the center of the bay and Madeira Bay located farther north adjacent to the Everglades on the mainland for comparative purposes.

Shell Key Basin is a mixed fauna, normal shallow-marine basin. Algae, bryozoans, sponges, and corals are abundant. The grass thickets are so dense in some areas that it is difficult to see anything else. There also is a profusion of forams, molluscs, and shrimp and an occasional *Diadema*. This diversity of fauna is lacking in Crab Key Basin, where the most abundant forms are *Thalassia, Acetabularia, Penicillus* with encrusting sponges and bryozoans, and shrimp mounds where the grass thickets are absent.

Madeira Bay by contrast is almost a barren basin. The water is turbid and murkiness is related to firmness of the bottom - the softer the more murky. The shallow basin is nearly surrounded by mangroves including many dead ones. Other than the abundant free-floating algae *Laurentia*, there is only *Thalassia* and other sea grasses and shrimp mounds in the bare areas.

The regional water chemistry trends that emerged from sampling in July 1982 were: from north to south the salinity decreased as did the pH and turbidity, and CO_2 dramatically increased (Table 2). These changes from nearshore brackish, restricted marine to open marine (normal) correspond to McCallum and Stockman's (1964) hydrographic zones in the bay. The temperature

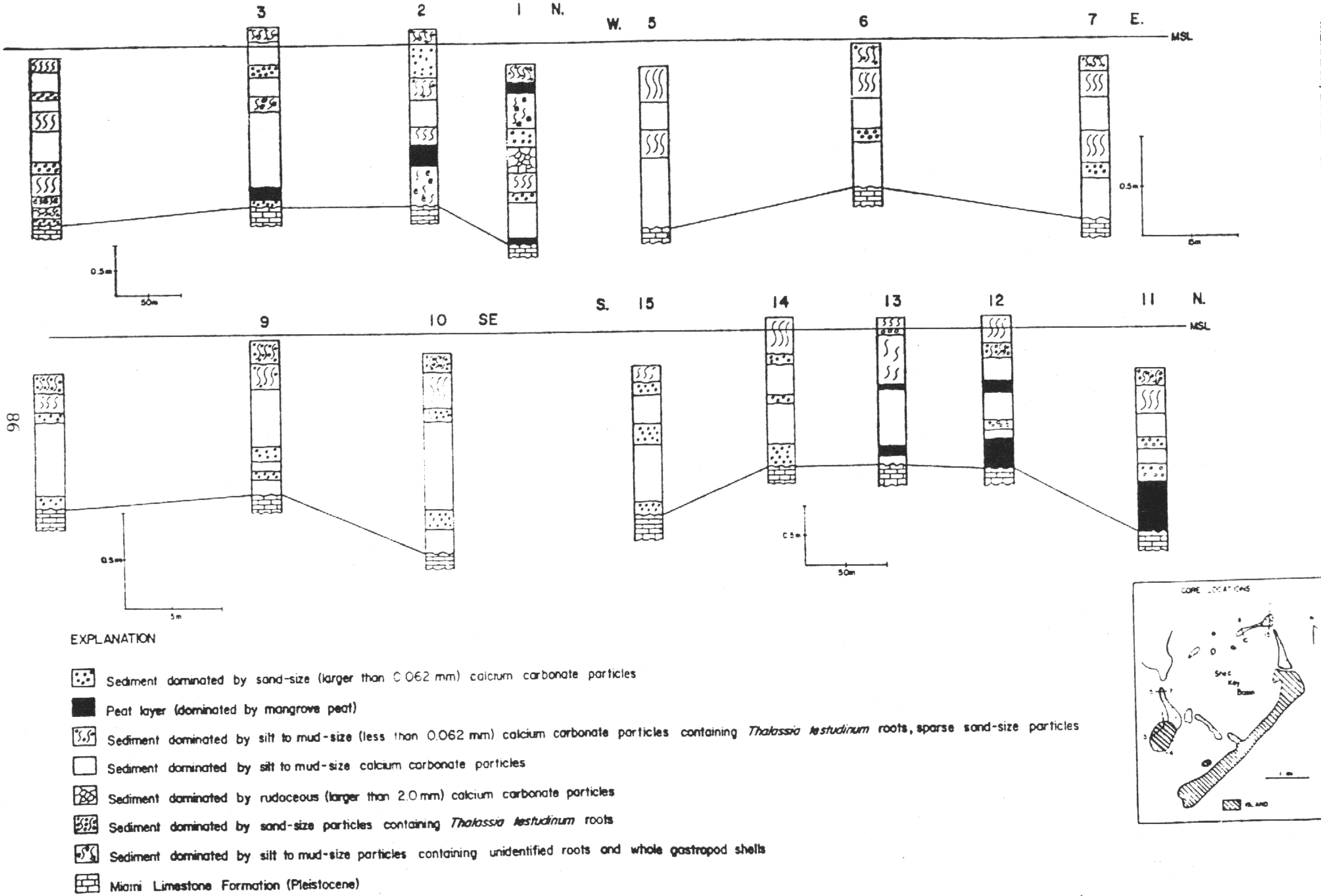


Figure 7. Cross sections of selected traverses of islands and mudbanks, Shell Key Basin.

remains constant in this part of Florida Bay. Variation in salinity is greater in the mainland-sheltered Madeira Bay, but the CO_2 is not as variable as farther south where biological activities load to greater dissolved CO_2 and pH. The higher average salinity in Madeira Bay is surprising, but extreme salinities can result from intense evaporation in areas of poor circulation (Ginsburg, 1956). The increased turbidity in the two northern basins is a function of the greater clay-size fraction which occurs there. The parameters not related to biologic activity can fluctuate dramatically as a function of rainfall.

STRATIGRAPHY

Soft-sediment cores were taken manually with 10-ft long coring device. Several lines were cored across the mudbanks and islands. Cores were extruded and halved on the spot for description. Selected samples were taken back to the laboratory for additional analysis. All cores were taken to bedrock. For the most part, the cores consist of fine-grained carbonate mud with layers of coarser material of shell hash; peat layers are present at several levels beneath the islands and Thalassia roots penetrate most cores. In addition, many probes were made to ascertain thickness of sediment and configuration on top of the Miami Limestone.

Mudbanks: Cores were taken on several of the mudbanks. The banks are asymmetrical with the north and west sides steeper and more shelly therefore more firm. Storms from the north and west winnow the fines leaving a lag of coarser material on the north and west side of the banks. The banks are composed of light-gray, fine-grained micrite intercalated with layers of coarse shell hash, which are probably storm layers (Fig. 7). No peat occurs under any of the banks. The upper parts of the cores contain decaying *Thalassia*. Corelation is difficult because of the lack of persistent recognizable layers.

Islands: Cores were taken across both Cotton Key and Shell Key. The islands are oval shaped in map section and saucer shaped in cross section. Typically the islands are ringed with mangroves and have a shallow pond in the center. The salinity of these interior ponds varies as a function of rainfall and evaporation. They can be hypersaline in the winter or have reduced salinities in the summer (P. Enos, 1983, pers. comm.). Cores revealed fine-grained micrite with intercalated layers of shell hash and peat (Fig. 7). Generally two peat layers underlie each island, but at least one is always present. Tentative correlations reveal a complex history of an early swamp environment followed by a marine episode which culminated into the present island and supratidal sediments.

The origin of the mudbanks and islands has been of interest for some time, Hoffmeister (1974) suggested that north-south rills developed on the Miami Limestone surface by the southward-flowing streams in a way similar to the present-day sloughs farther north in the Everglades. The rills were filled in first from south to north as the area was flooded by rising sealevel. The cross banks developed later. Plotting of the few basal radiocarbon dates in the bay (obtained from Davies, 1980) gives credence to this suggestion, as the dates are progressively younger to the north and east in the bay reflecting the progressive development of mangrove swamps with the sea transgression. Anomalous dates suggest low areas which may mark the location of the rills between known bedrock highs.

BEDROCK

The bedrock under Florida Bay is the bryozoan facies of the Miami Limestone (Enos and Perkins, 1977). Preliminary studies indicate that the surface of the Miami Limestone under the bay is similar to the rocks where exposed farther north on the mainland. In addition to detailed probing

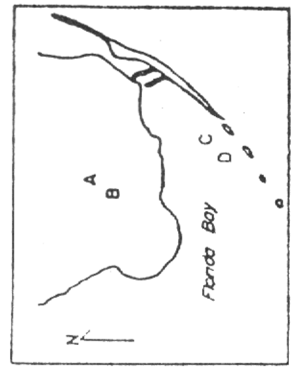
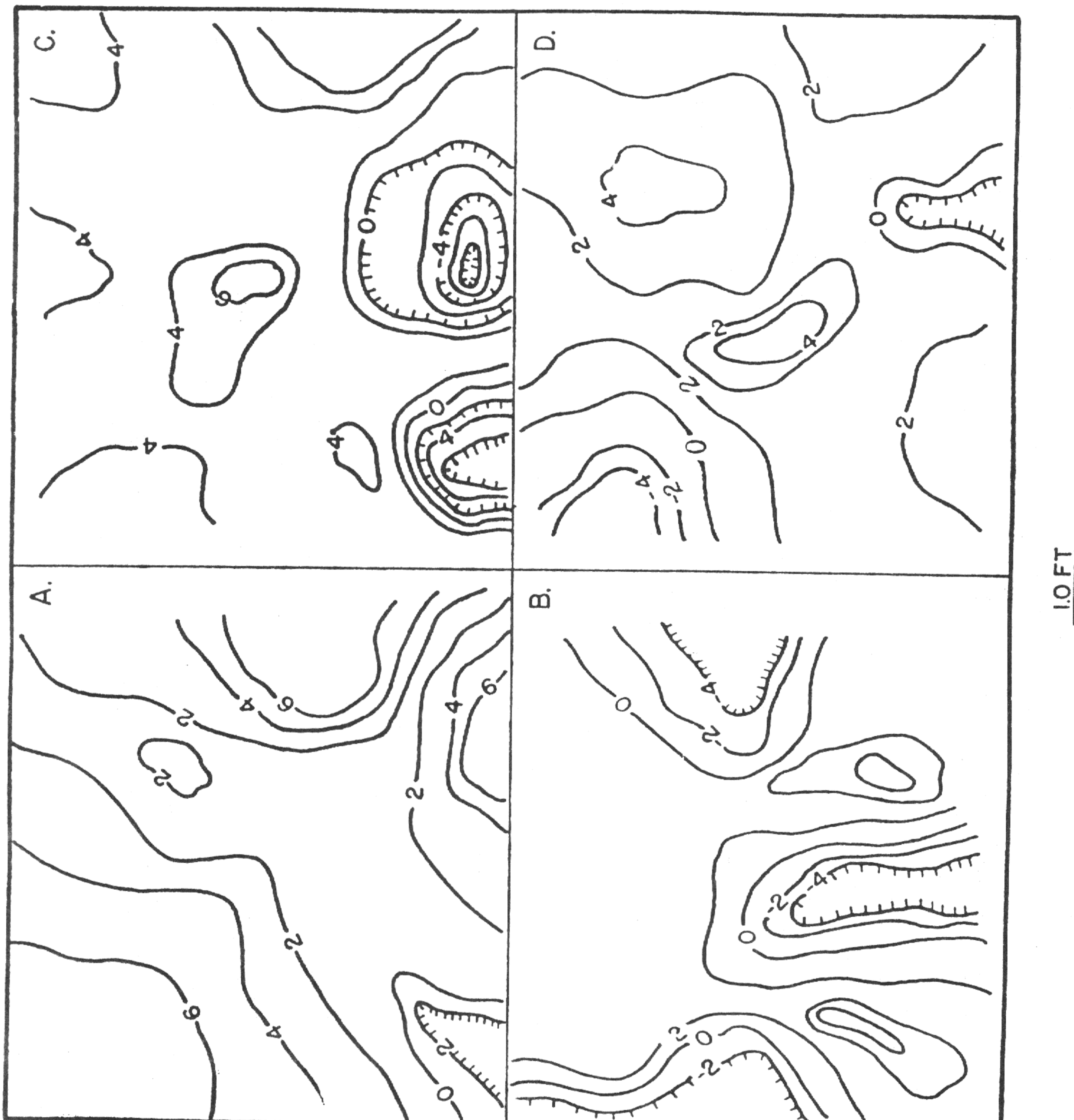


Figure 8.
Location of 5 ft. x 5 ft probe grids for microkarst comparisons of Miami Limestone Formation (bryozoan facies). Grids A and B; probed on surface exposures of Miami Limestone Formation in Everglades; grids C and D: probed through unconsolidated sediment in Florida Bay to Miami Limestone Formation underneath.



of the surface, numerous sonic depth profiles were made across the basin. No evidence of "rockreefs," such as exposed in the Everglades to the north, was found.

Rock reefs are several feet high and wide, and miles long. They are straight for the most part and trend east-west or slightly northwest or north-south. About ten of them have been identified. Their origin has been attributed to lithological differences, topographic features, or structural features (Frohlich, 1979). There is essentially no lithological difference between the rock reefs and the surrounding bedrock, although thin sections reveal a subtle textural variation across the reefs. The significance of this textural variation is not yet well understood. Thin sections show the reefs to be composed of shell fragments and pellets in a mud matrix (no oolites).

The Miami Limestone is essentially a flat-lying featureless surface sloping slightly to the southwest. An extensive microkarst is developed on the upper surface; such an intricate surface is well exposed in the Everglades especially during the dry season when the usual cover of saw grass does not obstruct the view. This surface was mapped in detail for comparison with the surface under Florida Bay which was mapped in detail by probing. Comparison of the configurations indicate that the same magnitude of karst features are present under the Bay (Fig. 8).

SUMMARY

Variation of the chemical constituents in the "lakes" are considerable thus indicating wide range of tolerance of the perennial organisms. Also, it has been found that:

(a) In general in the bay salinity decreases from north to south at least seasonally; CO_2 increases from north to south, pH decreases and then slightly increases from north to south; and the turbidity decreases from north to south. Therefore, the bay can be subdivided loosely into three zones with fuzzy limits from north to south: nearshore brackish, restricted marine, and open marine (normal).

(b) As the salinity and CO_2 decrease, the pH and turbidity increase.

Correlation of lithic units in cores is difficult on a broad scale, it will have to be done on a fine scale. Our study also reveals that microkarst and other features on the Miami Limestone in the bay are similar to the rocks exposed in areas farther to the north.

Additional work needs to be done in order to shed further light on, (a) island shape, (b) comparison of parameters from basin to basin, (c) relation of the different variables to each other, (d) compaction studies of the lime mud.

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